

CHIMERIC PEPTIDE IMMUNOGENS

This application claims priority from the provisional application No. 60/202,328, filed May 5, 2000 in the United States Patent and Trademark Offic.

FIELD OF THE INVENTION:

5 The invention is related to chimeric peptides having immunogenic efficacy, comprising a hormone epitope and promiscuous helper T-cell epitope for the production of high titers of anti-hormone antibodies.

BACKGROUNDOF THE INVENTION

The success of an antigenic composition is linked to its immunogenicity, that is, 10 the ability to produce a sufficiently high titer of antibodies to react or bind with the target antigen or so as to neutralize its effects. The immunogenicity depends on the effectiveness by which the antigen causes the body's immune system to mount a response which can be generally assessed on the basis of the antibody titer in the blood of the immunized animal or mammal including the human.

15 Antigenic formulations can be prepared for antigens of low immunogenicity with constructs or mixtures of an immunomimic epitope of the target antigen and an immunogen not related to the target antigen so as to generate a strong immune response against the entire immunogenic construct or mixture so as to be effective against the specific target antigen.

20 In order to enhance or potentiate the immune defense system, so-called adjuvants in the form of oily substances and other potentiating and emulsifying agents are added to the antigenic formulations. In general, the adjuvant is mixed into the immunogenic emulsion formulation and simultaneously delivered with the antigen in the same administration, e.g., by injection. Specifically, antigenic formulations have been enhanced 25 to target less immunogenic microorganisms or viral pathogens by the addition of so-called adjuvants comprising immune response-stimulating killed microbial cells, particles or fragments thereof. Moreover, immunogenic compositions may contain carrier components, including emulsions, liposomes, microparticles and implantable vehicles which may be metabolizable.

30 Immunization technology has been applied as a biological modifying means to immunize against various soluble and insoluble animal or human self-antigens, which are not normally recognized by the individual host's own immune defense, but which may be

rendered immunogenic so as to stimulate or potentiate the individual's own immune response system. The self-antigens may include the surfaces of certain cells which are malfunctioning or malignant, and small proteins, enzymes or intercellular signals, such as, e.g., hormones or other factors, and/or their cognate receptors, whether normal or deficient. The lack of immunogenicity of these self-antigens has been often overcome by complexing or linking the non-immunogenic self-antigens with a pharmaceutically acceptable, i.e. non-toxic, immunogenic carrier so as to produce antibodies capable of binding, thereby neutralizing, the self-antigen of the subject animal or human patient.

The immunological methods can be used for example in the therapeutical hormone control or regulation and the treatment of patients afflicted with a disorder or disease.

Some immunogens suitable for hormone-regulation comprise hormone immunomimicking molecular moieties which are conjugated or fused to immunogenic carriers, such as, e.g., proteins, or peptides or complex polysugars. The immunogenic constructs are usually administered as either an oil-in-water or a water-in-oil emulsion, containing an adjuvant capable of stimulating or potentiating an immune response.

An immune response is typically measured in terms of the production of specific anti-hormone antibodies. The hormones and cognate receptors which are targeted for control by the immunological methods are directly neutralized or inhibited by the antigen-binding reaction of circulating hormone specific antibodies elicited by the injected immunogenic constructs.

For example, an anti-hormone immunogen has been constructed to affect the regulation of the gonadotropin releasing hormone (see co-assigned U.S. Patent 5,688,506). The Gonadotropin Releasing Hormone (abbreviated "GnRH", also known as Luteinizing Hormone Releasing Hormone, abbreviated "LHRH"), is of central importance to the regulation of fertility. Johnson M et al., *Essential Reproduction*, 3rd Edn. Blackwell Scientific Publications (1988). In both males and females, GnRH is released from the hypothalamus into the bloodstream and is transported through the bloodstream to the pituitary, where it induces the release of gonadotropins, luteinizing hormone (LH) and follicle stimulating hormone (FSH), by the gonadotrophs. These gonadotropins, in turn, act upon the gonads, inducing steroidogenesis and gametogenesis. Steroids released from the gonads into the circulation subsequently act upon various tissues. This gonadotropin related hormonal cascade can be halted by the neutralization of the biological activity of GnRH. Fraser H.M., *Physiological Effects of Antibody to*

Lutenizing Hormone Releasing Hormone, *Physiological Effects of Immunity Against Reproductive Hormones*, Edwards and Johnson, Eds. Cambridge University Press (1976). As a consequence of GnRH neutralization, the gonadotropins and gonadal steroids are not released into the blood, and their biological activities are curtailed or
5 eliminated by the direct and indirect action of specific anti-GnRH antibodies. By eliminating the physiological activity of GnRH, the cascade of hormonal regulation of fertility is interrupted and gametogenesis ceases. Consequently, GnRH neutralization halts the production of gametes. Thus, GnRH neutralization is an effective means of contraception.

10 A number of important diseases are affected by gonadotropins and particularly gonadal steroid hormones. Such diseases include breast cancer, uterine and other gynecological cancers, endometriosis, uterine fibroids, benign prostatic hypertrophy and prostate cancer, among others. Removal of the gonadal steroid hormonal stimuli for these diseases constitutes an important means of therapy. An effective method of
15 accomplishing this is by immunologically neutralizing GnRH, to thereby eliminate or inhibit production of GnRH dependent gonadal steroids that induce and stimulate these diseases. McLachlan R.I. et al. Clinical Aspects of LHRH Analogues in Gynaecology: a Review, *British Journal of Obstetrics and Gynaecology*, 93:431-454 (1986); Conn P.M. et al. Gonadotropin-Releasing Hormone and Its Analogs, *New England Journal of Medicine*, 324:93-103 (1991) and Filicori M. GnRH Agonists and Antagonists, Current Clinical Status. *Drugs*, 35:63-82 (1988).

Since GnRH has the same amino acid sequence in all mammals (pGlu-His-Trp-Ser-Tyr-Gly-Leu-Arg-Pro-GlyNH₂, SEQ ID NO: 1 in the Sequence Listing), it is presumed that a single immunogen would be effective in all mammalian species, including
25 humans. An anti-GnRH immunogenic construct, comprising the GnRH immunomimic domain in the form of peptide analogues, may be linked or conjugated to a carrier protein which is effectively immunogenic, such as, e.g., diphtheria toxoid, tetanus toxoid, keyhole limpet hemocyanin, bovine serum albumin, Hemophilae pertussis extracts or filamentous Amycolata extracts. Consequently, the immune response to the GnRH-vaccine will be
30 mostly directed against the carrier protein and secondarily, the attached hormone epitope moiety. In general, as an alternative approach, the immunogenicity of the immunomimic peptide can be enhanced by chemical modification with diazosulfuric acid groups.

Various anti-GnRH immunogenic compositions have been useful for producing

specific anti-GnRH antibodies. Immunogenic conjugates of GnRH-immunomimic epitope peptide and immunogenic protein carriers have been used for immunization of vertebrate subjects against the hormone, GnRH (U.S. Patent No. 5,688,506).

As another example, anti-hormone immunogens have been constructed to affect or
5 inhibit the activity of the stomach hormone gastrin, in particular, the major forms of gastrin, gastrin G17 and gastrin G34 (see U.S. Patents 5,023,077, and 5,468,494). It has been found that especially G17 is involved in gastrointestinal disorders and diseases such as gastroesophageal reflux disease, gastric and duodenal ulceration and cancer.

However, it has been found that perhaps due to the comparatively huge size of the
10 attached immunogenic carrier proteins, the immunization of the conjugate can induce anti-epitope specific suppression of the antibody (Sad et al. Immunology, 1985, 74:559; Schutze et al. J. Immunol, 1985, 135:231). Therefore, much smaller immunogenic proteins have been tried. Accordingly, short synthetic T-helper epitopes have been introduced to replace the large carrier molecules in conjugates to improve the efficacy of
15 the anti-hormone or self antigenic immunogen. Sad et al. (Vaccine 1993, 11:1145-1149) synthesized peptides from DT and universal or highly promiscuous T-helper epitopes from TT (829-844 amino acids, SEQ ID NO: 2) or CSP (378-398 aa; SEQ ID NO: 3) in order to try to minimize genetic restriction of the immune response. To be effective, the GnRH vaccines of Sad et al. required Freund's Complete Adjuvant.

20 Gosh et al. (Int. Immunology, 1999, 11:1103-1110) reported that some synthetic LHRH (GnRH) chimeric vaccines elicited an immune response for sterilization of mice. However, the promiscuous helper T-cell (Th)-epitope candidate T1 (TT sequence 947-
967 aa, SEQ ID NO: 4) was not regarded promiscuous enough to be applicable for a large number of animal species. It was also reported that in a shift, antisera from second
25 bleedings reacted significantly with the anti-Th epitope (T2) and much less with the LHRH antigen.

SUMMARY OF THE INVENTION

The present invention provides to immunogens comprising a chimeric peptide of a hormone-immunomimic peptide epitope fused in sequence with an immunogenic epitope. The hormone immunogenic peptide can be fused either directly to or through a spacer 5 sequence to an immunogenic peptide epitope.

These fusion peptides combine at least one epitope of a target substance which may be non immunogen in its natural state with at least one immunogenic peptide sequence of suitable immunogenic proteins. The sequences of both target epitope and immunogen may be selected from the amino-terminal or carboxy-terminal region or both. 10 A peptide also can be synthesized from the internal region of the peptide or protein. The fusion product may be acetylated at the amino-terminal end and amidated at the carboxy-terminal end of the peptide sequence.

DJF An embodiment of the invention provides an anti-GnRH immunogen chimeric peptide construct comprising a suitable immunogenic epitope, such as, e.g., short peptide 15 sequences selected from the measles virus protein F (MVF), tetanus toxoid (TT), or malaria plasmodium falciparum CSP protein. The invention also provides for methods of immunization with a composition comprising a chimeric peptide with one or more GnRH epitopes.

BRIEF DESCRIPTION OF THE DRAWINGS

20 Figure 1 illustrates the mean Anti-GnRH antibody titers obtained from rabbits using chimeric anti-GnRH Immunogens A through J, and as controls, Immunogens K and L as well as conjugate immunogen C GnRH:DT; and

Figure 2 illustrates the relationship between gross muscle reaction score and mean anti-GnRH Antibody Titer on GnRH Chimeras and Controls.

DETAILED DESCRIPTION OF THE INVENTION

Chimeric peptides comprising GnRH mimicking epitopes have been constructed and useful in generating improved antibody titers.

Since self-antigen epitopes of gonadotropin releasing hormone (GnRH) are not inherently immunogenic the immune response may be aided by immunogenic constructs according to the invention wherein a target peptide epitope is located on the same synthesized peptide as is an immunogenic peptide epitope.

Several different chimeric peptides are described in Example 1.

EXAMPLE I

The peptide sequences combine a select promiscuous T-helper-epitope through an inserted short spacer peptide (e.g., 4-8 amino acids) with at least one target hormone peptide. Suitable spacers of this invention include but are not limited to the peptides comprising the following amino acid sequence, GPSL (see SEQ ID NO: 5); SSGPSL (SEQ ID NO: 6); and SSGPSLKL (SEQ ID NO: 7), which are inserted in the peptide chimera to isolate the three dimensional folding of the immunogenic peptide from that of the hormone peptide.

PMS
Promiscuous Th-epitope moieties from measles virus protein F (MSF) (sequence 288-302 aa, SEQ ID NO: 8), tetanus toxoid (TT) (sequence 947-967 aa, SEQ ID NO: 9, or sequence 830-844 aa, SEQ ID NO: 10) and malaria Plasmodium falciparum CSP protein (sequence 378-398 aa, SEQ ID NO: 11) are used in these constructs. The hormone immunomimic epitopes were attached to the N-terminal or the C-terminus of the spacer as shown below. All mammalian GnRH peptides including the human hormone, have the same sequence. The GnRH hormone immunomimic epitope sequence comprises 1-10 amino acids of mammalian GnRH when attached

to the aminoterminal peptide end and comprises 2-10 amino acids of mammalian GnRH when attached to the carboxyterminal peptide end. In addition, an immunomimic peptide comprising 13-16 amino acids of the mammalian GnRH comprise GnRH immunomimics peptides attached to both ends of the spacer, in order to increase the number of available 5 GnRH antigenic epitopes. The different peptide chimera fusion immunogens in terms of antibodies produced are described below.

Peptide 1.

→ Measles virus protein F sequence (288-302aa) →

10 NH2-K	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>
	L	L	S	E	I	K	G	V	I	V	H	R	L	E	
16 17 18	<u>19</u>	<u>20</u>	<u>21</u>	<u>22</u>											
	G	V	E	G	P	S	L	H	W	S	Y	G	L	R	P
31 G-CONH2	<p style="margin: 0;">← spacer →</p> <p style="margin: 0;">—————> GnRH (2-10 aa)</p>														

(SEQ ID NO: 9 in the Sequence Listing)

15

Peptide 2.

—————> Tetanus toxoid sequence (947-967 aa) ——————>

20 NH2-F	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>		
	N	N	F	T	V	S	F	W	L	R	V	P	K	V			
25 <u>31</u>	<u>16</u>	<u>17</u>	<u>18</u>	<u>19</u>	<u>20</u>	<u>21</u>											
	S	A	S	H	L	E	G	P	S	L	H	W	S	Y	G		
<u>32</u>	<p style="margin: 0;">← spacer →</p> <p style="margin: 0;">—————> GnRH (2-10aa)</p>																
	R	P	G-CONH2	(SEQ ID NO: 10 in the Sequence Listing)													

Peptide 3.

—————→ Tetanus toxoid sequence (830-844 aa) ←————

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>
NH ₂ -Q	Y	I	K	A	N	S	K	F	I	G	I	T	E	L

5 ← spacer → → GnRH 2-10 aa

<u>16</u>	<u>17</u>	<u>18</u>	<u>19</u>	<u>20</u>	<u>21</u>	<u>22</u>	<u>23</u>	<u>24</u>	<u>25</u>	<u>26</u>	<u>27</u>	<u>28</u>
G	P	S	L	H	W	S	Y	G	L	R	P	G-CONH ₂

(SEQ ID NO: 11 in the Sequence Listing)

10

Peptide 4.

—————→ Malaria CSP Protein Sequence 378-398 aa ←————

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>
NH ₂ -D	E	K	K	I	A	K	M	E	K	A	S	S	V	F

—————→ ← spacer → — GnRH (sequence 2-10 aa)

<u>16</u>	<u>17</u>	<u>18</u>	<u>19</u>	<u>20</u>	<u>21</u>	<u>22</u>	<u>23</u>	<u>24</u>	<u>25</u>	<u>26</u>	<u>27</u>	<u>28</u>	<u>29</u>	<u>30</u>
N	V	V	N	S	G	P	S	L	H	W	S	Y	G	L

20 31 32 33 G-CONH₂ (SEQ ID NO: 12 in the Sequence Listing)

Peptide 5.

GnRH (sequence 1-10 aa) → ← spacer →

5	<u>1</u> p-E	<u>2</u> H	<u>3</u> W	<u>4</u> S	<u>5</u> Y	<u>6</u> G	<u>7</u> L	<u>8</u> R	<u>9</u> P	<u>10</u> G		<u>11</u> S	<u>12</u> S	<u>13</u> G	<u>14</u> P	<u>15</u> S
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← MVF-P (288-302 aa) →

10	<u>16</u> L	<u>17</u> K	<u>18</u> L	<u>19</u> L	<u>20</u> S	<u>21</u> E	<u>22</u> I	<u>23</u> K	<u>24</u> G	<u>25</u> V	<u>26</u> I	<u>27</u> V	<u>28</u> H	<u>29</u> R	<u>30</u> L
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31
E 32
G 33
V E-COOH (SEQ ID NO: 13 in the Sequence Listing)

Peptide 6.

→ GnRH (sequence 1-10 aa) → ← spacer →

15	<u>1</u> p-E	<u>2</u> H	<u>3</u> W	<u>4</u> S	<u>5</u> Y	<u>6</u> G	<u>7</u> L	<u>8</u> R	<u>9</u> P	<u>10</u> G		<u>11</u> S	<u>12</u> S	<u>13</u> G	<u>14</u> P	<u>15</u> S
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TT sequence 947-967 aa →

20	<u>16</u> L	<u>17</u> F	<u>18</u> N	<u>19</u> N	<u>20</u> F	<u>21</u> T	<u>22</u> V	<u>23</u> S	<u>24</u> F	<u>25</u> W	<u>26</u> L	<u>27</u> R	<u>28</u> V	<u>29</u> P	<u>30</u> K
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→ 31
V 32
S 33
A 34
S 35
H 36
L 37
E-COOH (SEQ ID NO: 14 in the Sequence Listing)

Peptide 7.

| GnRH sequence 1-10 aa → ← spacer →

<u>1</u> p-E	<u>2</u> H	<u>3</u> W	<u>4</u> S	<u>5</u> Y	<u>6</u> G	<u>7</u> L	<u>8</u> R	<u>9</u> P	<u>10</u> G						<u>11</u> S	<u>12</u> S	<u>13</u> G	<u>14</u> P	<u>15</u> S
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5 TT sequence 830-844 aa →

<u>16</u> L	<u>17</u> Q	<u>18</u> Y	<u>19</u> I	<u>20</u> K	<u>21</u> A	<u>22</u> N	<u>23</u> S	<u>24</u> K	<u>25</u> F	<u>26</u> I	<u>27</u> G	<u>28</u> I	<u>29</u> T
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10 30 31
E L-COOH (SEQ ID NO: 15 in the Sequence Listing)

Peptide 8.

15 | GnRH sequence 1-10 aa → ← spacer →

<u>1</u> p-E	<u>2</u> H	<u>3</u> W	<u>4</u> S	<u>5</u> Y	<u>6</u> G	<u>7</u> L	<u>8</u> R	<u>9</u> P	<u>10</u> G						<u>11</u> S	<u>12</u> S	<u>13</u> G	<u>14</u> P	<u>15</u> S
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← M-CSP sequence 378-398 aa →

<u>16</u> L	<u>17</u> D	<u>18</u> E	<u>19</u> K	<u>20</u> K	<u>21</u> I	<u>22</u> A	<u>23</u> K	<u>24</u> M	<u>25</u> E	<u>26</u> K	<u>27</u> A	<u>28</u> S	<u>29</u> S	<u>30</u> V
----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------

20 →
31
F 32
N 33
V 34
V 35
N 36
S-COOH (SEQ ID NO: 16 in the Sequence Listing)

Peptide 9.

GnRH (sequence 1-10 aa) → ← spacer →

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>		<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>
p-E	H	W	S	Y	G	L	R	P	G		S	S	G	P	S

5 ←———— MVF-P (288-302 aa) —————→

<u>16</u>	<u>17</u>	<u>18</u>	<u>19</u>	<u>20</u>	<u>21</u>	<u>22</u>	<u>23</u>	<u>24</u>	<u>25</u>	<u>26</u>	<u>27</u>	<u>28</u>	<u>29</u>	<u>30</u>
L	K	L	L	S	E	I	K	G	V	I	V	H	R	L

← spacer → —————→ GnRH (2-10 aa)

<u>10</u>	<u>31</u>	<u>32</u>	<u>33</u>	<u>34</u>	<u>35</u>	<u>36</u>	<u>37</u>	<u>38</u>		<u>39</u>	<u>40</u>	<u>41</u>	<u>42</u>	<u>43</u>	<u>44</u>	<u>45</u>	<u>46</u>
	E	G	V	E	G	P	S	L		H	W	S	Y	G	L	R	P

47
G-CONH2 (SEQ ID NO: 17 in the Sequence Listing)

15

Peptide 10.

→ GnRH (sequence 1-10 aa) —————→ ← spacer →

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>		<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>
p-E	H	W	S	Y	G	L	R	P	G		S	S	G	P	S

20 TT sequence 947-967 aa —————→

<u>16</u>	<u>17</u>	<u>18</u>	<u>19</u>	<u>20</u>	<u>21</u>	<u>22</u>	<u>23</u>	<u>24</u>	<u>25</u>	<u>26</u>	<u>27</u>	<u>28</u>	<u>29</u>	<u>30</u>
L	F	N	N	F	T	V	S	F	W	L	R	V	P	K

—————→ ← spacer → —————→ GnRH (2-10) —————→

<u>25</u>	<u>31</u>	<u>32</u>	<u>33</u>	<u>34</u>	<u>35</u>	<u>36</u>	<u>37</u>	<u>38</u>	<u>39</u>	<u>40</u>	<u>41</u>	<u>42</u>	<u>43</u>	<u>44</u>	<u>45</u>	<u>46</u>
	V	S	A	S	H	L	E	G	P	S	L	H	W	S	Y	G

47 48 49 50
L R P G-CONH2 (SEQ ID NO: 18 in the Sequence Listing)

1102865-0047

Peptide 11.

| GnRH sequence 1-10 aa → ← spacer →

1	2	3	4	5	6	7	8	9	10	11 S	12 S	13 G	14 P	15 S
p-E	H	W	S	Y	G	L	R	P	G					

5 TT sequence 830-844 aa →

16	17 L	18 Q	19 Y	20 I	21 K	22 A	23 N	24 S	25 K	26 F	27 I	28 G	29 T	

10 ← spacer → → GnRH (2-10 aa) →

30	31 E	32 L	33 S	34 S	35 G	36 P	37 S	38 L	39 H	40 W	41 S	42 Y	43 G	44 L	45 R	46 P

15 46
G-CONH₂ (SEQ ID NO: 19 in the Sequence Listing)

Peptide 12.

| GnRH sequence 1-10 aa → ← spacer →

1	2	3	4	5	6	7	8	9	10	11 S	12 S	13 G	14 P	15 S
p-E	H	W	S	Y	G	L	R	P	G					

20 ← M-CSP sequence 378-398 aa →

16	17 L	18 D	19 E	20 K	21 I	22 A	23 K	24 M	25 E	26 K	27 A	28 S	29 S	30 V

25 → ← spacer → → GnRH (sequence 2-10 aa)

31	32 <u>47</u> F	33 N	34 V	35 V	36 N	37 S	38 S	39 G	40 P	41 S	42 L	43 H	44 W	45 S	46 Y

30 →

48 49 50 51

EXAMPLE II

Immunogenicity tests were performed with five chimeric peptide immunogens
5 against GnRH. Each chimeric peptide contained one region encoding an epitope to be
recognized by helper T-cell and a second region encoding an immunomimic of GnRH, to
serve as the target for the antibody response. The chimeric peptide immunogens were
formulated to deliver 100, 250 or 500 µg doses of peptide with 3µg norMDP, in a water
in oil emulsion. Control immunogens were prepared to deliver 500 µg of mammalian
10 GnRH (1-10) Ser1 peptide (which is normally linked to an immunogenic carrier to impart
immunogenicity), with and without norMDP (3 µg), in the same emulsions. The
immunogens were given intramuscularly to rabbits in three injections, on days 0, 14 and
42. An ELISA procedure was used to measure the resultant anti-GnRH antibody
responses in sera collected at 14-day intervals over the course of the immunization.
15 Injection site reactions were assessed by visual and microscopic evaluations on day 84.

The following materials were used in the immunogenicity tests. The five
immunogens of GnRH chimera peptides tested were selected from the aforementioned
Peptide 1 through 16.

1. GnRH chimera 1 {MVF (Measles Virus Protein F)} "Peptide 1" (MW 3427.17)
- 20 2. GnRH chimera 2 {TT-3 (Tetanus Toxoid Epitope 3)} "Peptide 2" (MW 3886.52)
3. GnRH chimera 3 {TT-2 (Tetanus Toxoid Epitope 2)} "Peptide 3" (MW 3132.6)
4. GnRH chimera 4 {MCSP (Malaria Circumsporozoite Protein)} "Peptide 4" (MW 3632.2)
5. GnRH chimera 6 (TT-3, N-ter GnRH) "Peptide 6" (MW 4172.7)
- 25 6. D17 Peptide ("GnRH (1-10) Ser 1")

For testing the GnRH chimeric peptide immunogens were formulated at
concentrations listed below in Table 1. Each injection volume was 0.2 ml/dose (see Table
2).

Table 1. GnRH Chimera and Control Immunogen Formulations

Immunogen	Chimeric Peptide	Concentration of Peptide in Emulsion (mg/ml)	Peptide Dose (µg/dose)	Concentration of norMDP in Emulsion (mg/ml)	norMDP Dose (µg/dose)
A	Peptide 1	2.5	500	0.015	3
B	Peptide 2	2.5	500	0.015	3
C	Peptide 2	1.25	250	0.015	3
D	Peptide 2	0.5	100	0.015	3
E	Peptide 3	1.25	500	7.2×10^{-3}	3
F	Peptide 4	2.5	500	0.015	3
G	Peptide 6	2.5	500	0.015	3
H	Peptide 2	2.5	500	0.015	3
I	Peptide 3	1.25	500	7.2×10^{-3}	3
J	Peptide 2 & 3	0.625, each peptide	250, each peptide	7.2×10^{-3}	3
K	D17 Peptide	2.5	500	0.015	3
L	D17 peptide	2.5	500	-	-

The GnRH chimeric immunogenic compositions and control immunogens were formulated under clean conditions in the combinations shown in Table 1. The test materials were sterile bottled and stored under refrigeration (2-8°C).

New Zealand White female rabbits were immunized with GnRH chimera and control immunogens as shown in Table 2. Injections were given to each rabbit on days 0, 14 and 42 in dose volumes of either 0.2 ml or 0.4 ml. All immunogens were given IM, at injection sites tattooed for later identification.

To assess immunogenicity, sera were obtained from each rabbit every 14 days until day 84. Anti-GnRH antibody titers were measured in the sera samples by a direct binding ELISA. All values, with the exception of those for immunogen 6, are expressed relative to a reference standard rabbit anti-GnRH serum reference titer of 5,000. Titers of sera against Immunogen 6 (Peptide 6 N-terminal specific antibodies) were expressed relative to the reference standard rabbit anti-GnRH serum Ser 10(11) reference titer of 20,000.

Although the original study had two rabbit groups, the protocol was later amended to add two more groups ($n=4$), 3 and 4, with amounts of 250 μg and 100 μg of GnRH chimera 2 (TT-3) (Peptide 2), each with 3 μg of norMDP.

Table 2. Example II: Immunization Schedule

Rabbit Group Number	N*	Peptide(s)	Injection Volume (ml/dose)
1	4	Peptide 1 500 μg	0.2
2	4	Peptide 2 500 μg	0.2
3	4	Peptide 2 250 μg	0.2
4	4	Peptide 2 100 μg	0.2
5	4	Peptide 3 500 μg	(2 x 0.2/site)**
6	4	Peptide 4 500 μg	0.2
7	4	Peptide 6 500 μg	0.2
8	10	Peptide 2 500 μg	0.2
9	10	Peptide 3 500 μg	(2 x 0.2/site)**
10	6	Peptides 2 & 3, 250 μg each	(2 x 0.2/site)**
11	4	D17 peptide (500 μg) with norMDP	0.2
12	4	D17 peptide 500 μg	0.2

5 * N=number of rabbits per group

** Peptide 3 did not dissolve at higher concentrations, therefore injection volumes were doubled to deliver 500 $\mu\text{g}/\text{dose}$ of total peptide.

Since GnRH chimera peptide 3 ("Peptide 3") (TT-2) was not found soluble at
 10 9.412 mg/ml in aqueous phase, the original protocol was amended to reduce the concentration in half (4.706 mg/ml) and double the dose volume to maintain 0.2 ml

volume per injection (2×0.2 ml/site). Injection #3 was delivered on day 42.

Titers obtained for the individual serum samples are given in Table 3A/B/C, and mean titers for all groups are plotted in Figure 1, respectively. In the initial tests, all rabbits responded to the chimera peptides with the production of anti-GnRH antibody titers.

5 Peptide 3 or GnRH chimera 3 (TT-2) induced significantly higher antibody titers in comparison with the other chimera peptides. Peptide 2 or Chimera 2 was most immunogenic at the $500\text{ }\mu\text{g}$ dose (Immunogen B), with the $100\text{ }\mu\text{g}$ (Immunogen D) and $250\text{ }\mu\text{g}$ (Immunogen C) doses inducing weaker titers. Chimeras 2 (Immunogen B) and 3 (Immunogen E) induced high antibody titers in the initial tests ($n=4$) relative to titers
10 induced by GnRH:DT; however, these titers were lower in the repeat studies ($n=10$, Immunogen H where the response rate was quite variable, and Immunogen I, respectively).

A combination of Chimeras 2 and 3 (Immunogen J), at $250\text{ }\mu\text{g}$ dose of each (half the dose used in rabbits injected with the individual peptides) induced high titers of
15 anti-GnRH antibody. Chimeras 1 (Immunogen A), 4 (Immunogen F) and 6 (Immunogen G) were not as potent as the GnRH:DT conjugate formulated in Montanide ISA 703 (as historical control included in Figures 1 and 2). It should be noted that Peptide 6 or GnRH chimera 6 (TT-3 in aminoterminal position) titers were measured using an N-terminus specific reference standard, therefore a statistical comparison of these titers with other
20 chimera peptides was not performed. Nevertheless, Peptide 6 was concluded not to be an effective immunogen. Very low anti-GnRH antibody titers were induced by D17 peptide adjuvanted with norMDP (Immunogen K), while without norMDP (Immunogen L), the D17 peptide emulsion was not immunogenic.

Gross pathology of injection sites was assessed on all rabbits on day 84. The
25 evaluation was scored on a scale of 0-3, where a score of 0 indicated normal tissue appearance and 3 indicated the presence of extensive tissue inflammation. Scores of 1 or 2 were judged intermediate levels of local reaction.

Table 3A. Example II: Anti-GnRH Antibody Titers for GnRH Chimeras

Immunogen	Injection→	Injection 1 (Day 0)	Injection 2 (Day 14)		Injection 3 (Day 42)			
	Rabbit #	Day 0	Day 14	Day 28	Day 42	Day 56	Day 70	Day 84
A	1	0	274	3,276	8,845	12,500	20,600	13,200
	2	0	0	636	2,193	4,667	13,400	8,249
	3	0	0	198	512	731	1,392	1,166
	4	0	0	0	0	0	0	0
	Mean	0	69	1,028	2,888	4,475	8,848	5,654
	Median	0	0	417	1,353	2,699	7,396	4,708
	S.D.	0	137	1,522	4,081	5,729	9,878	6,213
B	5	0	8,201	20,500	37,400	34,500	62,100	76,800
	6	0	12,400	46,400	81,200	134,000	93,100	108,000
	7	0	507	22,300	91,800	75,000	50,600	28,400
	8	0	589	2,085	16,100	24,800	31,800	32,700
	Mean	0	5,424	22,821	56,625	67,075	59,400	61,475
	Median	0	4,395	21,400	59,300	54,750	56,350	54,750
	S.D.	0	5,886	18,181	35,838	49,632	25,705	37,953
C	9	0	0	536	1,325	6,631	7,267	5,033
	10	0	0	1,240	3,551	19,700	19,600	7,886
	11	0	0	719	16,800	12,800	16,800	11,200
	12	0	0	454	2,671	5,017	5,844	3,692
	Mean	0	0	737	6,087	11,037	12,378	6,953
	Median	0	0	628	3,111	9,716	12,034	6,460
	S.D.	0	0	353	7,201	6,679	6,844	3,328
D	13	0	2,952	8,320	869	87,200	47,300	39,700
	14	0	841	21,600	57,500	93,000	25,100	11,800
	15	0	141	1,759	4,373	7,732	6,670	5,198
	16	0	0	5,220	7,044	7,363	6,120	4,731
	Mean	0	984	9,225	17,447	48,824	21,298	15,357
	Median	0	491	6,770	5,709	47,466	15,885	8,499
	S.D.	0	1,363	8,674	26,822	47,721	19,450	16,546
E	17	0	1,382	15,500	140,000	79,900	136,000	105,000
	18	0	264	13,200	50,800	41,700	120,000	145,000
	19	0	471	13,000	98,900	95,700	111,000	131,000
	20	0	2,317	13,400	35,900	52,800	80,500	85,100
	Mean	0	1,109	13,775	81,400	67,525	111,875	116,525
	Median	0	927	13,300	74,850	66,350	115,500	118,000
	S.D.	0	941	1,162	47,423	24,703	23,332	26,713
F	21	0	296	3,189	2,638	2,165	2,751	3,365
	22	0	0	441	5,920	4,912	8,760	12,200
	23	0	0	484	6,350	6,333	7,900	7,512
	24	0	0	3,556	60,300	20,400	24,300	18,700
	Mean	0	74	1,918	18,802	8,453	10,928	10,444
	Median	0	0	1,837	6,135	5,623	8,330	9,856
	S.D.	0	148	1,687	27,716	8,151	9,301	6,582

Table 3B. Example II: Anit-GnRH Antibody Titers for GnRH Chimeras continued)

Immunogen	Injection→	Injection 1 (Day 0)	Injection 2 (Day 14)		Injection 3 (Day 42)			
	Rabbit #	Day 0	Day 14	Day 28	Day 42	Day 56	Day 70	Day 84
G	25	0	0	0	0	105	640	1,165
	26	0	0	0	0	0	131	141
	27	0	0	0	166	914	3,554	3,830
	28	0	0	0	191	387	1,265	1,510
	Mean	0	0	0	89	352	1,398	1,662
	Median	0	0	0	83	246	953	1,338
H	S.D.	0	0	0	104	409	1,511	1,558
	29	0	0	0	208	708	693	
	30	0	0	1,257	1,475	2,800	2,374	2,313
	31	0	0	0	0	0	0	
	32	0	0	0	147	1,319	2,051	1,559
	33	0	204	3,713	8,696	11,900	14,100	11,200
	34	0	0	413	480	**	16,900	14,700
	35	0	0	366	326	1,879	3,462	3,022
	36	0	0	0	0	200	410	555
	37	0	0	163	774	2,825	4,677	5,109
	38	0	2,787	8,027	7,742	41,700	63,200	62,900
I	Mean	0	299	1,394	1,964	6,981	10,788	10,205
	Median	0	0	265	403	1,879	2,918	2,668
	S.D.	0	877	2,597	3,335	13,523	19,319	19,149
	39	0	0	228	877	7,841	12,200	9,998
	40	0	0	2,568	5,522	27,000	29,600	17,000
	41	0	895	7,474	31,400	29,500	46,300	34,500
J	42	0	0	1,560	3,280	10,800	12,000	11,500
	43	0	222	3,510	16,600	20,600	31,300	26,500
	44	0	0	5,825	22,500	27,000	36,200	37,900
	45	0	1,249	24,300	39,300	65,000	67,700	69,100
	46	0	498	5,208	7,243	8,877	13,500	16,800
	47	0	0	2,091	5,509	10,100	19,200	18,300
	48	0	0	4,072	7,937	14,600	26,300	48,400
	Mean	0	286	5,684	14,017	22,132	29,430	29,000
	Median	0	0	3,791	7,590	17,600	27,950	22,400
	S.D.	0	452	6,886	13,061	17,164	17,535	18,782
K	49	0	219	4,179	33,900	81,500	85,300	113,000
	50	0	8,659	100,00	193,000	242,000	169,000	129,000
	51	0	305	0	89,500	91,300	97,800	69,000
	52	0	1,071	14,800	26,600	30,600	27,500	19,300
	53	0	554	11,000	64,000	32,500	31,400	31,100
	54	0	1,940	16,300	86,400	70,500	65,600	68,800
L	Mean	0	2,125	29,830	82,333	91,400	79,433	71,700
	Median	0	813	15,550	75,200	76,000	75,450	68,900
	S.D.	0	3,263	35,647	60,172	77,950	52,134	43,356
	C1	0	746	1,515	2,201	1,918	2,074	1,913
	C2	0	0	0	0	0	0	0
	C3	0	134	590	953	998	1,238	1,768
C4	0	323	2,279	1,345	1,225	1,640	987	
	Mean	0	301	1,096	1,125	1,035	1,238	1,167
	Median	0	229	1,053	1,149	1,112	1,439	1,378
	S.D.	0	325	1,005	913	793	893	878
	C5	0	0	0	0	0	0	0
	C6	0	0	0	0	0	0	0
C7	0	0	0	0	107	0	0	0
	C8	0	0	0	0	0	0	0
	Mean	0	0	0	0	27	0	0
	Median	0	0	0	0	0	0	0
	S.D.	0	0	0	0	54	0	0

Table 3C. Example II: Anti-GnRH Antibody Titers for GnRH Chimeras

Immunogen	Injection→	Injection 1 (Day 0)	Injection 2 (Day 14)		Injection 3 (Day 42)			
	Rabbit #	Day 0	Day 14	Day 28	Day 42	Day 56	Day 70	Day 84
Control	C9	0	475	7,210	11,400	8,812	8,762	8,338
GnRHDT Conjugate in Emulsion = 0.5 mg/ml	C10	0	1,588	9,253	20,100	28,500	34,800	32,200
Conjugate Dose = 100 µg	C11	0	0	4,593	17,700	25,100	35,400	19,800
Dose Volume = 0.2 ml	C12	0	194	3,647	7,900	13,900	12,900	11,800
	C13	0	169	1,565	2,559	4,752	7,204	7,115
	C14	0	651	3,965	3,755	8,277	13,700	7,179
	C15	0	123	2,785	2,627	4,198	5,218	3,891
	C16	0	353	4,910	13,800	26,700	43,600	30,600
	C17	0	333	8,573	25,100	30,300	57,400	26,200
	C18	0	188	2,171	2,622	7,314	8,207	8,404
	Mean, Group 5	0	407	4,867	10,756	15,785	22,719	15,553
	Median, Group 5	0	264	4,279	9,650	11,356	13,300	10,102
	S.D.	0	455	2,653	8,216	10,617	18,486	10,695

* test titers are read at 20,000 titer of the reference standard, lot 122298SHG2

The score data are summarized in Table 4, indicating that most of the visual injection site scores ranged from 0 to 1, indicating that the immunogens were generally well tolerated.

5 Histologic readings of the injection site biopsies which were performed as of day 84 were in accord with the gross evaluation.

These experiments demonstrated that chimera peptides carrying a T-lymphocyte epitope and expressing an immunomimic of GnRH can be used to induce potent anti-GnRH antibody responses. Peptides bearing TT-2 and TT-3 T-lymphocyte epitopes, derived from TT, were more effective than the T-lymphocyte epitopes derived from MVF and MCSP. A combination of the TT-2 and TT-3 bearing chimeras was particularly effective. It was surprisingly found that the GnRH epitope had to be on the carboxyterminus of the chimeras to be immunogenic. Most injection site reactions were of an acceptable level. Overall, the response compared favorably with those induced by the GnRH:DT (previously named, D17-DT) conjugate, indicating that the 10 synthetic peptides could potentially enhance the choice of effective immunogens and perhaps even replace the conjugate method for producing an active component of the GnRH immunogen.

Table 4. Example II: Reaction Scores

Immunogen	MEAN REACTION SCORES						REACTION SCORES >1					
	Injection 1		Injection 2		Injection 3		Injection 1		Injection 2		Injection 3	
	SITE 1	SITE 2	SITE 1	SITE 2	SITE 1	SITE 2	SITE 1	SITE 2	SITE 1	SITE 2	SITE 1	SITE 2
A	0		0.5		0.5		0		0		0	
B	0.4		1.1		1.1		0		1		1	
C	0.1		0.5		0.5		0		0		0	
D	0.3		0.4		1.0		0		0		1	
E	0.6	0.3	0.9	0.6	0.8	1.3	0	0	1	0	0	1
F	0.5		1.1		1.1		0		1		1	
G	0.1		0.3		0.8		0		0		0	
H	0.1		0.3		0.4		0		0		0	
I	0	0.4	0.1	0.5	0.6	0.7	0	0	0	0	1	1
J	0	0.4	0.5	0.5	1.0	1.3	0	0	0	0	1	2
K	0.4		0.4		1.0		0		0		1	
L	0.3		0		0.3		0		0		0	
Conjugate Ctl.	0.4		0.6		0.9		0		0		1	